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Itagaki et al.

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(54) **OCCUPANCY DETECTION DEVICE AND OCCUPANCY DETECTION METHOD**

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B61L 1/10 (2006.01)
B61L 3/12 (2006.01)

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(52) **U.S. Cl.**

CPC ... ***B61L 1/02*** (2013.01); ***B61L 1/10*** (2013.01); ***B61L 3/125*** (2013.01); *B61L 25/025* (2013.01); *B61L 27/0077* (2013.01)

(58) **Field of Classification Search**

CPC B61L 1/02; B61L 1/10; B61L 3/121; B61L 3/125; B61L 25/025; B61L 27/0077

USPC .... 246/20, 27, 28 R, 34, 122 R

See application file for complete search history.

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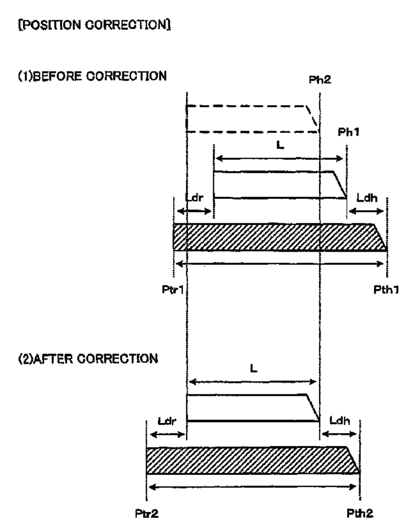
(57) **ABSTRACT**

An onboard system transmits a train occupancy range based on a measured train position to a ground system. The ground system provisionally detects the occupancy state of each block section based on the train occupancy range acquired from the onboard system. Exit detection points (Qh, Qr) are set at a position outside each block section. It is determined that the train has left the block section when the entirety of the train occupancy range has passed the exit detection point (Qh, Qr). When the provisional detection result indicates that the detection target block section is not occupied, and it has been determined that the train has left the detection target block section, it is determined that the detection target block section is not occupied.

7 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

B61L 25/02	(2006.01)
B61L 27/00	(2006.01)

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FIG. 1

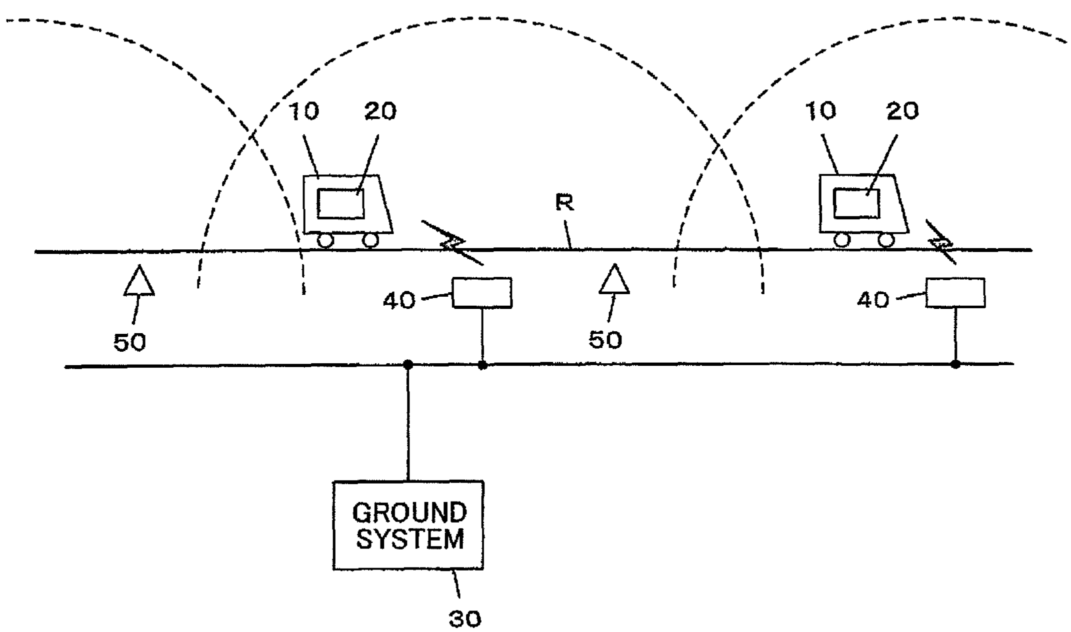


FIG. 2

[TRAIN OCCUPANCY RANGE]

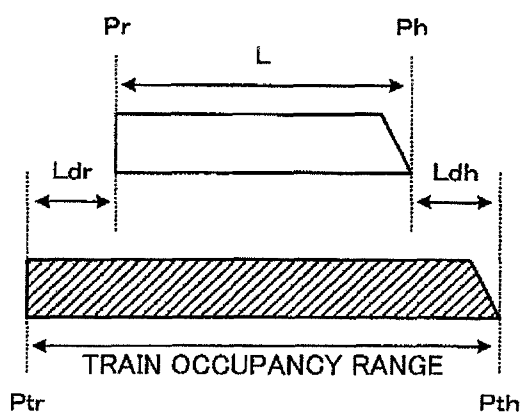
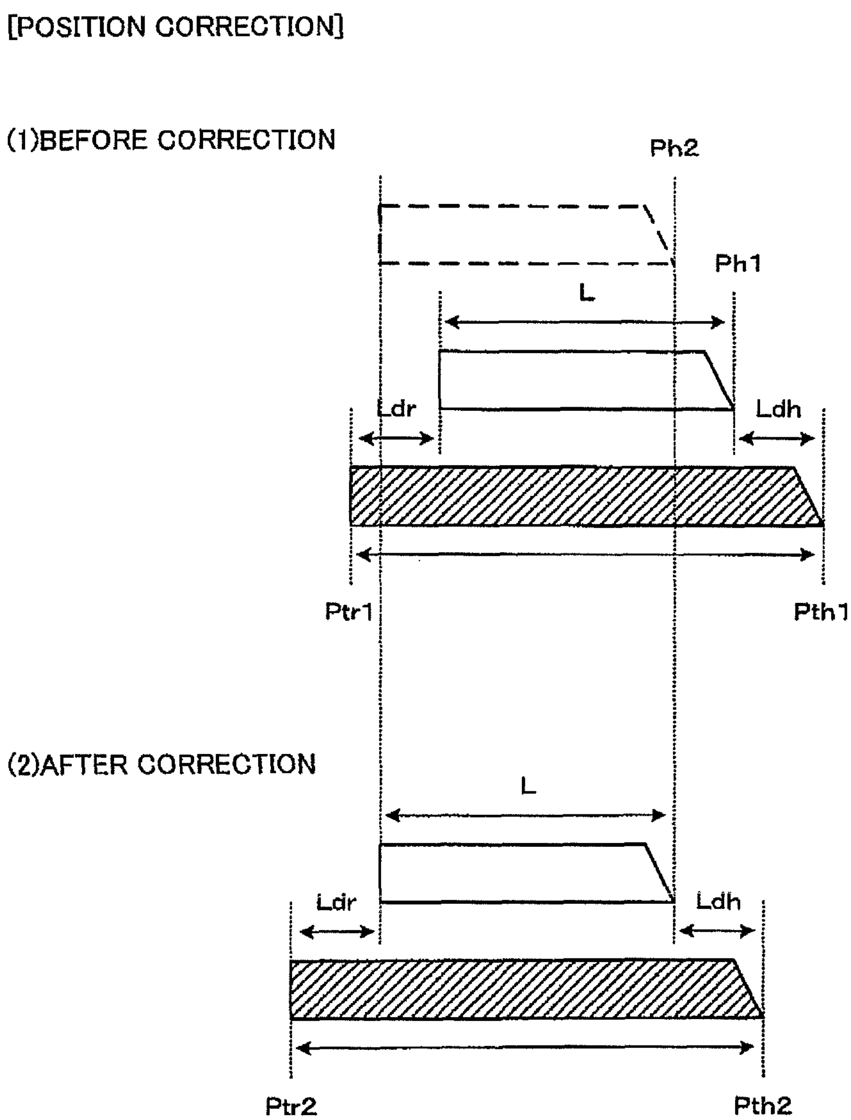


FIG. 3



[POSITION CORRECTION]
(1)BEFORE CORRECTION
Ph2
Ph1
L
Ldr
Ldh
Ptr1
Pth1
(2)AFTER CORRECTION
L
Ldr
Ldh
Ptr2
Pth2

FIG. 4

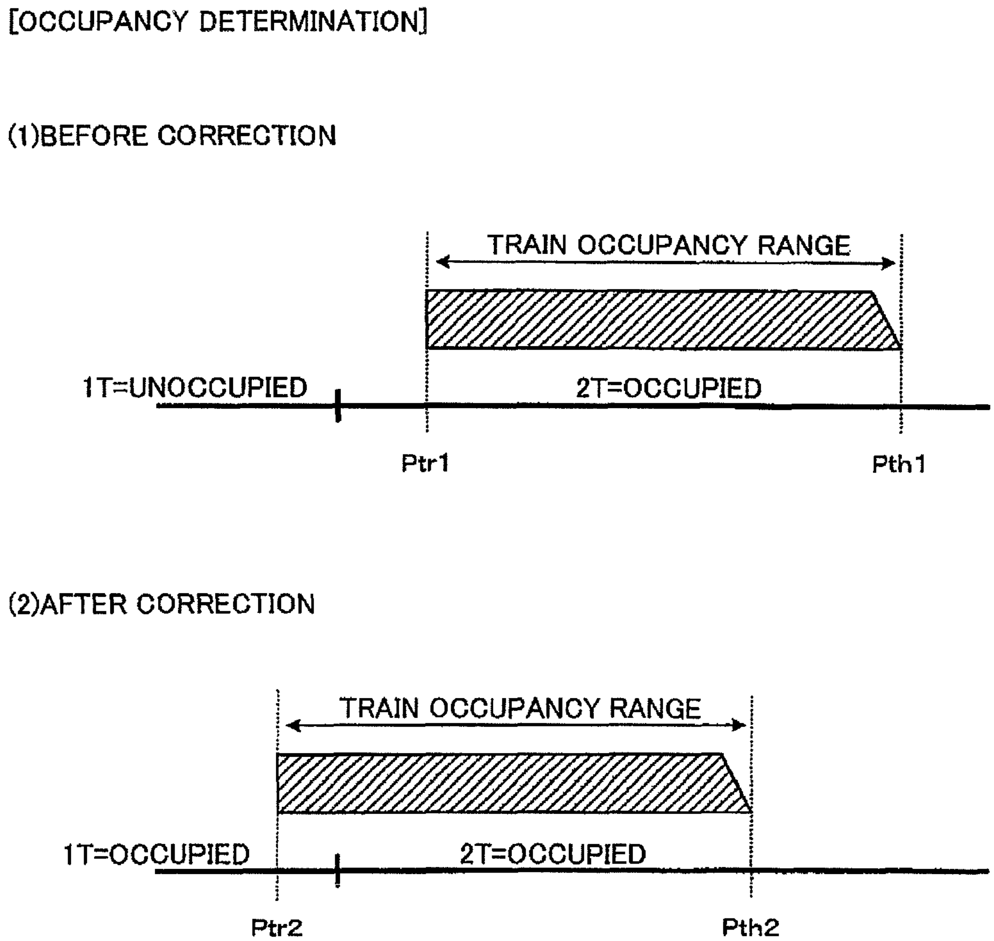

[OCCUPANCY DETERMINATION]
(1)BEFORE CORRECTION
TRAIN OCCUPANCY RANGE
1T=UNOCCUPIED
2T=OCCUPIED
Ptr1
Pth1
(2)AFTER CORRECTION
TRAIN OCCUPANCY RANGE
1T=OCCUPIED
2T=OCCUPIED
Ptr2
Pth2

FIG. 5

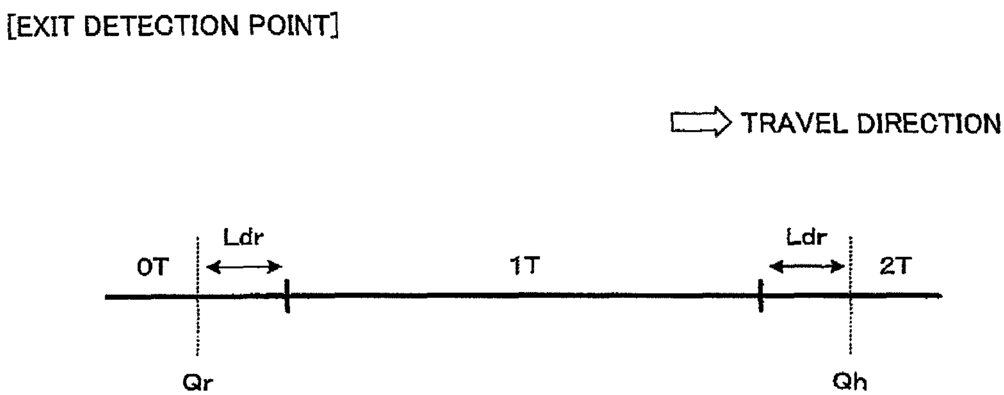


FIG. 6

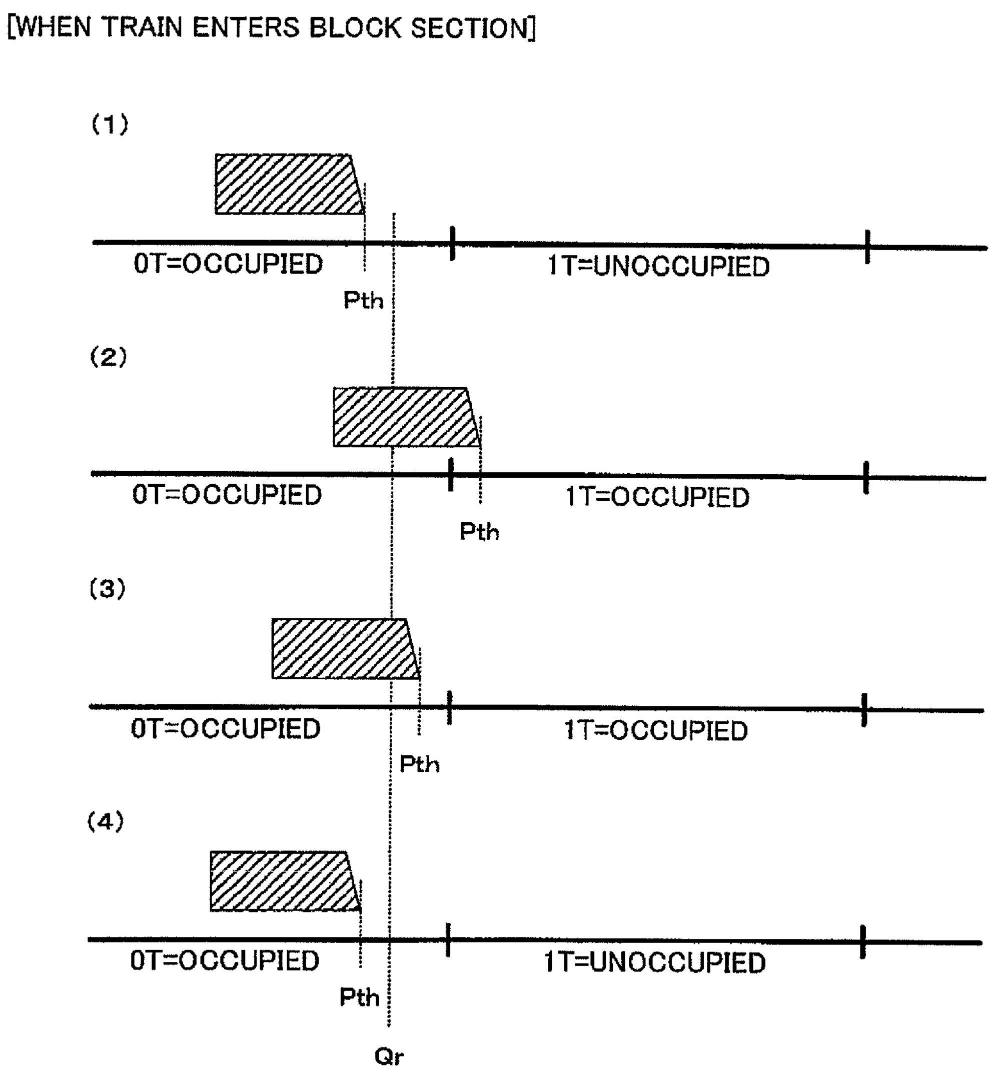

[WHEN TRAIN ENTERS BLOCK SECTION]
(1)
0T=OCCUPIED
1T=UNOCCUPIED
Pth
(2)
0T=OCCUPIED
1T=OCCUPIED
Pth
(3)
0T=OCCUPIED
1T=OCCUPIED
Pth
(4)
0T=OCCUPIED
1T=UNOCCUPIED
Pth
Qr

FIG. 7

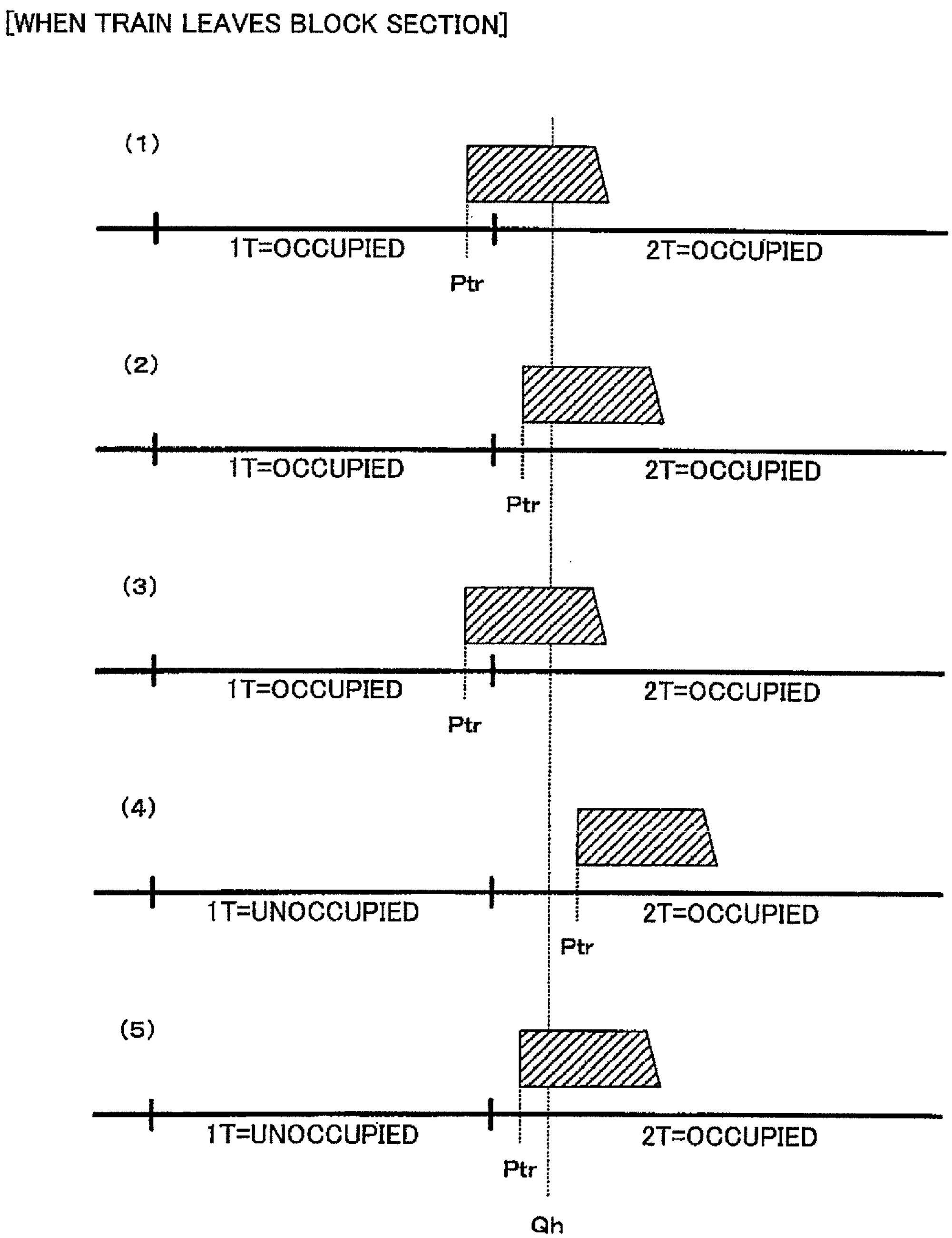

[WHEN TRAIN LEAVES BLOCK SECTION]
(1)
1T=OCCUPIED
2T=OCCUPIED
Ptr
(2)
1T=OCCUPIED
2T=OCCUPIED
Ptr
(3)
1T=OCCUPIED
2T=OCCUPIED
Ptr
(4)
1T=UNOCCUPIED
2T=OCCUPIED
Ptr
(5)
1T=UNOCCUPIED
2T=OCCUPIED
Ptr
Qh

FIG. 8

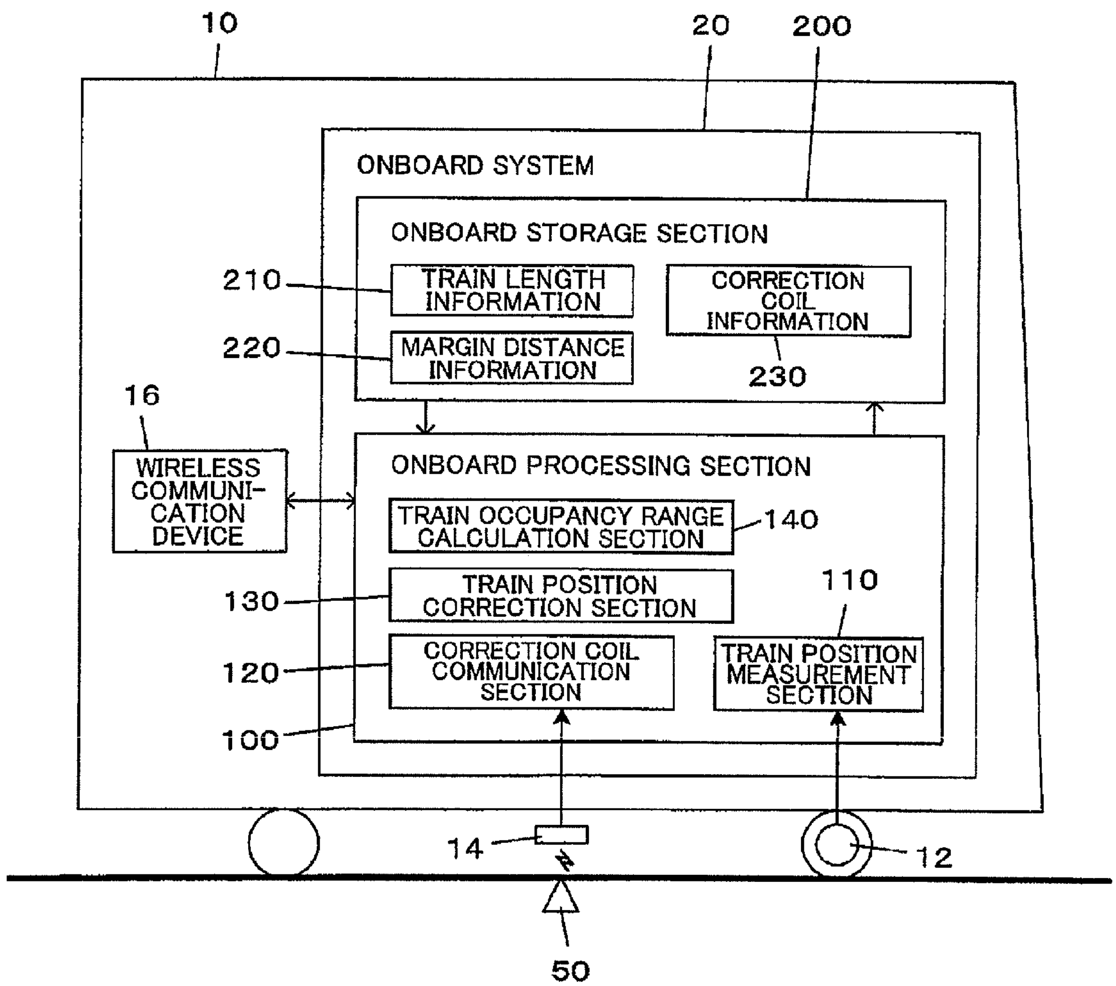

10
20
200
ONBOARD SYSTEM
ONBOARD STORAGE SECTION
210
TRAIN LENGTH INFORMATION
CORRECTION COIL INFORMATION
220
MARGIN DISTANCE INFORMATION
230
16
WIRELESS COMMUNI-CATION DEVICE
ONBOARD PROCESSING SECTION
TRAIN OCCUPANCY RANGE CALCULATION SECTION
140
130
TRAIN POSITION CORRECTION SECTION
110
120
CORRECTION COIL COMMUNICATION SECTION
TRAIN POSITION MEASUREMENT SECTION
100
14
12
50

FIG. 9

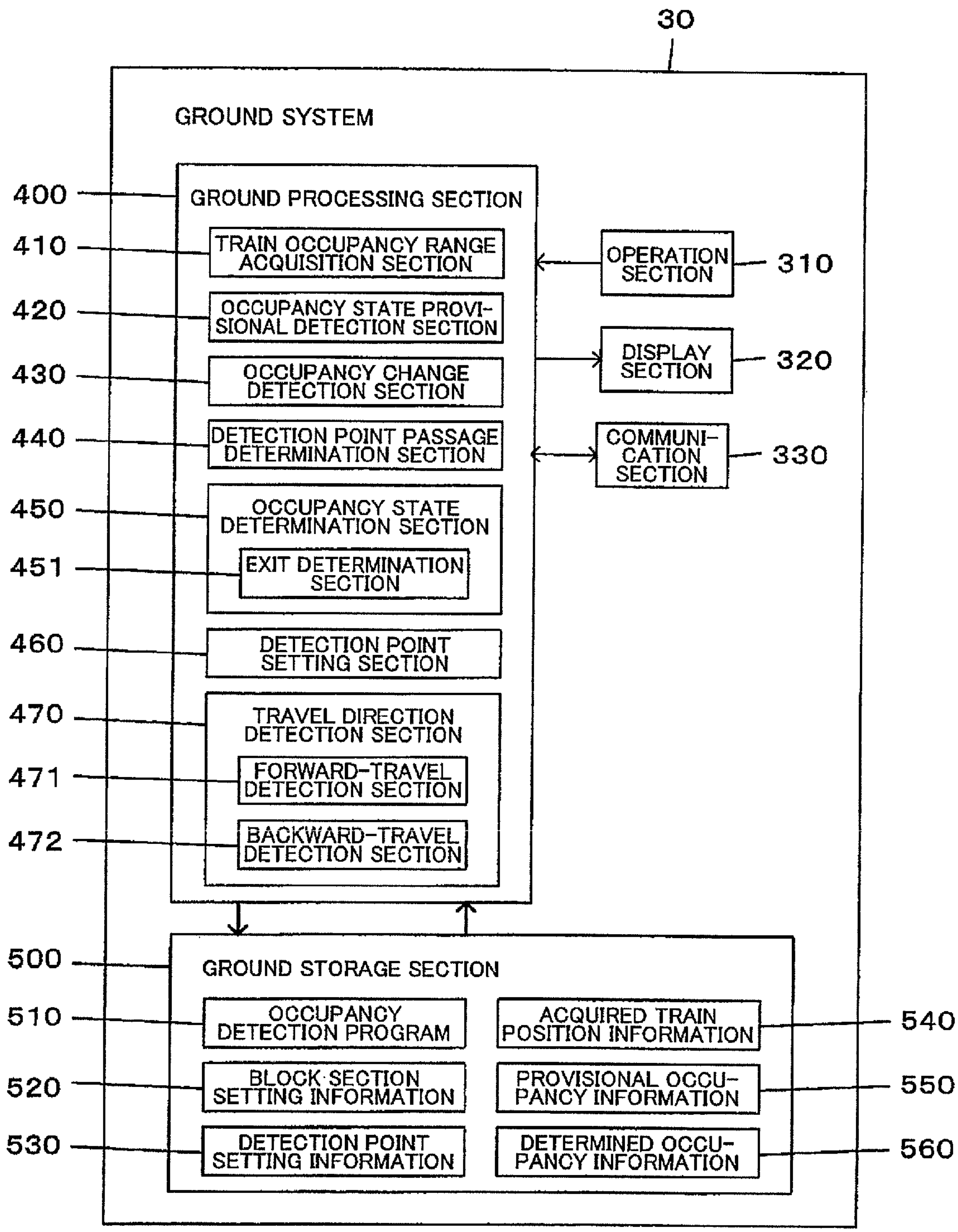

30
GROUND SYSTEM
400
GROUND PROCESSING SECTION
410
TRAIN OCCUPANCY RANGE ACQUISITION SECTION
420
OCCUPANCY STATE PROVISIONAL DETECTION SECTION
430
OCCUPANCY CHANGE DETECTION SECTION
440
DETECTION POINT PASSAGE DETERMINATION SECTION
450
OCCUPANCY STATE DETERMINATION SECTION
451
EXIT DETERMINATION SECTION
460
DETECTION POINT SETTING SECTION
470
TRAVEL DIRECTION DETECTION SECTION
471
FORWARD-TRAVEL DETECTION SECTION
472
BACKWARD-TRAVEL DETECTION SECTION
OPERATION SECTION
310
DISPLAY SECTION
320
COMMUNICATION SECTION
330
500
GROUND STORAGE SECTION
510
OCCUPANCY DETECTION PROGRAM
520
BLOCK SECTION SETTING INFORMATION
530
DETECTION POINT SETTING INFORMATION
ACQUIRED TRAIN POSITION INFORMATION
540
PROVISIONAL OCCUPANCY INFORMATION
550
DETERMINED OCCUPANCY INFORMATION
560

FIG. 10

520

521 522 523

BLOCK SECTION	START POINT POSITION	END POINT POSITION
1T	L1	L2
2T	L2	L3
3T	L3	L4
⋮	⋮	⋮

[BLOCK SECTION SETTING INFORMATION]

FIG. 11

550

551 552

BLOCK SECTION	PROVISIONAL OCCUPANCY STATE
1T	UNOCCUPIED
2T	OCCUPIED
3T	UNOCCUPIED
⋮	⋮

[PROVISIONAL OCCUPANCY INFORMATION]

FIG. 12

560

561 562

BLOCK SECTION	DETERMINED OCCUPANCY STATE
1T	OCCUPIED
2T	UNOCCUPIED
3T	UNOCCUPIED
⋮	⋮

[DETERMINED OCCUPANCY INFORMATION]

FIG. 13

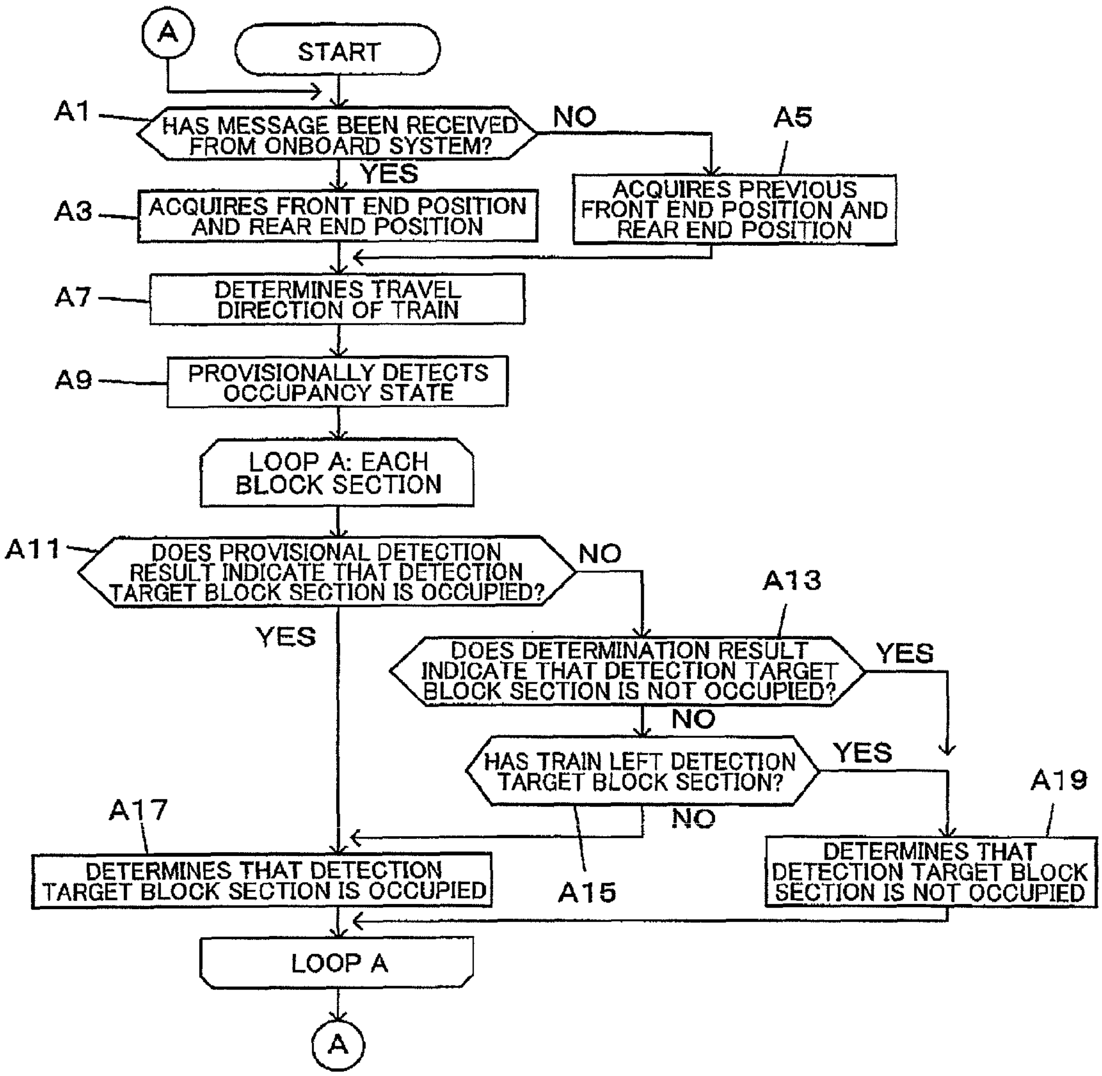
530

531 532 533

BLOCK SECTION	BACKWARD EXIT DETECTION POINT Qr	FORWARD EXIT DETECTION POINT Qh
1T	L11	L12
2T	L21	L22
3T	L31	L32
⋮	⋮	⋮

[DETECTION POINT SETTING INFORMATION]

FIG. 14


A
START
A1
HAS MESSAGE BEEN RECEIVED FROM ONBOARD SYSTEM?
NO
A5
YES
A3
ACQUIRES FRONT END POSITION AND REAR END POSITION
ACQUIRES PREVIOUS FRONT END POSITION AND REAR END POSITION
A7
DETERMINES TRAVEL DIRECTION OF TRAIN
A9
PROVISIONALLY DETECTS OCCUPANCY STATE
LOOP A: EACH BLOCK SECTION
A11
DOES PROVISIONAL DETECTION RESULT INDICATE THAT DETECTION TARGET BLOCK SECTION IS OCCUPIED?
NO
A13
YES
DOES DETERMINATION RESULT INDICATE THAT DETECTION TARGET BLOCK SECTION IS NOT OCCUPIED?
YES
NO
HAS TRAIN LEFT DETECTION TARGET BLOCK SECTION?
YES
A19
A17
NO
DETERMINES THAT DETECTION TARGET BLOCK SECTION IS OCCUPIED
A15
DETERMINES THAT DETECTION TARGET BLOCK SECTION IS NOT OCCUPIED
LOOP A
A

OCCUPANCY DETECTION DEVICE AND OCCUPANCY DETECTION METHOD

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of International Patent Application No. PCT/JP2012/077683, having an international filing date of Oct. 26, 2012, which designated the United States, the entirety of which is incorporated herein by reference.

BACKGROUND

In recent years, development of the Communications-Based Train Control (CBTC) system that does not require a track circuit has progressed. The CBTC system is configured so that an onboard system measures position information about the train, and transmits the position information to a ground system via wireless communication, and the ground system detects the position of the train based on the position information to control the train.

The onboard system detects the train position by measuring the rotational speed of a tacho-generator attached to the axle, for example, and the measured train position contains a measurement error. A technique that utilizes a range obtained by adding a margin distance (train length correction value) to the actual train length when detecting occupancy using the ground system has been proposed (see Japanese Patent No. 4575807, for example).

A technique has been generally used that corrects the train position based on the installation position (absolute position) of a correction coil acquired through communication with the correction coil when the train passes by the correction coil provided along the track in order to reduce a measurement error of the train position measured by the onboard system.

When correcting the train position by utilizing the correction coil, the train position may change (i.e., may be shifted forward/backward) due to correction. The ground system of the CBTC system determines whether or not each block section is occupied by a train based on the train position received from the onboard system. However, a change in train position due to correction may pose a problem when determining whether or not each block section is occupied by a train.

Specifically, when the train position measured by the onboard system precedes the actual train position, the train position is corrected backward when the train has passed by the correction coil. For example, when the rear end of the train that has been present within a second block section that follows a first block section is returned to the first block section due to backward correction, it is determined that the first block section is not occupied before correction, but is occupied after correction. Specifically, the first block section that has been detected to be unoccupied by the train that travels forward is occupied by the train again. In this case, the following train that is entering the first block section must be stopped rapidly since the following train is not allowed to enter the first block section. The above problem also occurs when the train position is corrected forward.

SUMMARY

According to a first aspect of the invention, there is provided an occupancy detection device that detects an occupancy state of each block section by a train, each block section being obtained by dividing a track, a correction coil being installed along the track, and the train including a measurement section that measures a train position, a correction coil communication section that communicates with the correction coil when the train passes by an installation point of the correction coil, and a correction section that corrects the train position based on a communication result of the correction coil communication section, the occupancy detection device comprising:

an acquisition section that acquires a train occupancy range that is determined based on the train position, the train occupancy range being a range in which the train may be present;

a provisional detection section that provisionally detects the occupancy state of each block section based on the train occupancy range;

a detection point passage determination section that determines whether or not the entirety of the train occupancy range has passed a detection point that is provided within a second block section adjacent to a first block section at a position away from a boundary between the first block section and the second block section by a given distance; and

a determination section that determines the occupancy state of the first block section using a detection result of the provisional detection section and a determination result of the detection point passage determination section.

According to a second aspect of the invention, there is provided an occupancy detection method that detects an occupancy state of each block section by a train, each block section being obtained by dividing a track, a correction coil being installed along the track, and the train including a measurement section that measures a train position, a correction coil communication section that communicates with the correction coil when the train passes by an installation point of the correction coil, and a correction section that corrects the train position based on a communication result of the correction coil communication section, the occupancy detection method comprising:

provisionally detecting the occupancy state of each block section based on a train occupancy range that is determined based on the train position, the train occupancy range being a range in which the train may be present;

determining whether or not the entirety of the train occupancy range has passed a detection point that is provided within a second block section adjacent to a first block section at a position away from a boundary between the first block section and the second block section by a given distance; and

determining the occupancy state of the first block section using a result of the provisionally detection and a determination result as to whether or not the entirety of the train occupancy range has passed a detection point.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view illustrating the configuration of a wireless train control system.

FIG. **2** is a view illustrating a train occupancy range.

FIG. **3** is a view illustrating position correction that utilizes a correction coil.

FIG. **4** is a view illustrating a problem that may occur due to position correction.

FIG. **5** is a view illustrating an exit detection point setting method.

FIG. **6** is a view illustrating determination of an occupancy state when a train enters a block section.

FIG. **7** is a view illustrating determination of an occupancy state when a train leaves a block section.

FIG. **8** is a view illustrating the configuration of an onboard system.

FIG. **9** is a view illustrating the configuration of a ground system.

FIG. **10** illustrates a data configuration example of block section setting information.

FIG. **11** illustrates a data configuration example of provisional occupancy information.

FIG. **12** illustrates a data configuration example of determined occupancy information.

FIG. **13** illustrates a data configuration example of detection point setting information.

FIG. **14** is a flowchart illustrating an occupancy detection process.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

According to one embodiment of the invention, there is provided an occupancy detection device that detects an occupancy state of each block section by a train, each block section being obtained by dividing a track, a correction coil being installed along the track, and the train including a measurement section that measures a train position, a correction coil communication section that communicates with the correction coil when the train passes by an installation point of the correction coil, and a correction section that corrects the train position based on a communication result of the correction coil communication section, the occupancy detection device comprising:

an acquisition section that acquires a train occupancy range that is determined based on the train position, the train occupancy range being a range in which the train may be present;

a provisional detection section that provisionally detects the occupancy state of each block section based on the train occupancy range;

a detection point passage determination section that determines whether or not the entirety of the train occupancy range has passed a detection point that is provided within a second block section adjacent to a first block section at a position away from a boundary between the first block section and the second block section by a given distance; and

a determination section that determines the occupancy state of the first block section using a detection result of the provisional detection section and a determination result of the detection point passage determination section.

According to another embodiment of the invention, there is provided an occupancy detection method that detects an occupancy state of each block section by a train, each block section being obtained by dividing a track, a correction coil being installed along the track, and the train including a measurement section that measures a train position, a correction coil communication section that communicates with the correction coil when the train passes by an installation point of the correction coil, and a correction section that corrects the train position based on a communication result of the correction coil communication section, the occupancy detection method comprising:

provisionally detecting the occupancy state of each block section based on a train occupancy range that is determined based on the train position, the train occupancy range being a range in which the train may be present;

determining whether or not the entirety of the train occupancy range has passed a detection point that is provided within a second block section adjacent to a first block section at a position away from a boundary between the first block section and the second block section by a given distance; and

determining the occupancy state of the first block section using a result of the provisionally detection and a determination result as to whether or not the entirety of the train occupancy range has passed a detection point.

According to the above configuration, the occupancy state of the first block section is determined using the provisional detection result for the occupancy state of each block section based on the train occupancy range, and the determination result as to whether or not the entirety of the train occupancy range has passed the detection point that is provided within the second block section adjacent to the first block section.

The occupancy detection device may further comprise:

an occupancy change detection section that detects whether or not the provisional detection section has detected that the occupancy state of the first block section has changed from an occupied state to an unoccupied state,

the determination section may include an exit determination section that 1) determines that the train has not left the first block section when the detection point passage determination section has determined that the entirety of the train occupancy range has not passed the detection point, and 2) determines that the train has left the first block section when the detection point passage determination section has determined that the entirety of the train occupancy range has passed the detection point, after the occupancy change detection section has detected that the provisional detection section has detected that the occupancy state of the first block section has changed from the occupied state to the unoccupied state, and

the determination section may determine that the first block section is occupied until the exit determination section determines that the train has left the first block section after the occupancy change detection section has detected that the provisional detection section has detected that the occupancy state of the first block section has changed from the occupied state to the unoccupied state.

According to the above configuration, the occupancy state of the first block section is determined as described below. Specifically, it is determined that the first block section is occupied until it is determined that the train has left the first block section after it has been provisionally detected that the occupancy state of the first block section has changed from the occupied state to the unoccupied state. It is determined that the train has not left the first block section when the train occupancy range has not passed the detection point, and determined that the train has left the first block section when the entirety of the train occupancy range has passed the detection point. Specifically, it is determined that the first block section is occupied until it is determined that the entirety of the train occupancy range has passed the detection point provided within the second block section even if it has been provisionally detected that the first block section is occupied since the train occupancy range is situated outside the first block section.

This prevents a situation in which the block section that has been detected to be unoccupied by the train that travels forward is occupied by the train again due to backward position correction using the correction coil.

In the occupancy detection device,

the second block section may be a block section that is adjacent to the first block section in a forward travel direction of the train,

the occupancy detection device may further comprise a forward-travel detection section that detects whether or not the train travels forward based on a change in the train occupancy range,

the detection point passage determination section may determine whether or not the entirety of the train occupancy range has passed the detection point based on the occupancy state of the second block section detected by the provisional detection section, and a positional relationship between a rear end position of the train occupancy range and the detection point, and

the exit determination section may determine whether or not the train that travels forward has left the first block section.

According to the above configuration, when the train travels forward, whether or not the entirety of the train occupancy range has passed the detection point is determined based on the positional relationship between the rear end position of the train occupancy range and the detection point that is provided within the second block section adjacent to the first block section in the forward travel direction of the train. It is determined that the train that travels forward has left the first block section when it has been determined that the entirety of the train occupancy range has passed the detection point.

In the occupancy detection device,

the second block section may be a block section that is adjacent to the first block section in a backward travel direction of the train,

the occupancy detection device may further comprise a backward-travel detection section that detects whether or not the train travels backward based on a change in the train occupancy range,

the detection point passage determination section may determine whether or not the entirety of the train occupancy range has passed the detection point based on the occupancy state of the second block section detected by the provisional detection section, and a positional relationship between a front end position of the train occupancy range and the detection point, and

the exit determination section may determine whether or not the train that travels backward has left the first block section.

According to the above configuration, when the train travels backward, whether or not the entirety of the train occupancy range has passed the detection point is determined based on the positional relationship between the front end position of the train occupancy range and the detection point that is provided within the second block section adjacent to the first block section in the backward travel direction of the train. It is determined that the train that travels backward has left the first block section when it has been determined that the entirety of the train occupancy range has passed the detection point.

The occupancy detection device may further comprise:

a detection point setting section that determines a position of the detection point by determining a distance from the boundary to the detection point based on a distance from the installation point of the correction coil to the boundary.

According to the above configuration, the distance from the boundary between the first block section and the second block section to the detection point is determined based on the distance from the installation point of the correction coil to the boundary. The train occupancy range is determined based on the train position and a margin distance that allows a measurement error. It is considered that a measurement error of the train position is small immediately after the train has passed by the installation point of the correction coil, and increases as the travel distance after the train has passed by the installation point of the correction coil increases. Therefore, whether or not the train has left the first block section can be quickly and reliably determined by setting the detection point at a position based on the distance from the installation point of the correction coil to the boundary.

Exemplary embodiments of the invention are described below with reference to the drawings. Note that the invention is not limited to the following exemplary embodiments.

System Configuration

FIG. **1** illustrates an outline of a wireless train control system **1** according to one embodiment of the invention. The wireless train control system **1** detects whether or not each virtual block section obtained by virtually dividing a track is occupied by a train.

The wireless train control system **1** includes an onboard system **20** that is mounted on a train **10**, and a ground system **30**. The onboard system **20** and the ground system **30** can communicate with each other via wireless communication through a given communication channel including a wireless base station **40**. A plurality of wireless base stations **40** are provided along a track R so that the track R is continuously included in the wireless communication area. Note that the communication channel may be implemented using a loop antenna or a leakage coaxial cable (LCX cable) provided along the track R instead of using a wireless base station.

The onboard system **20** measures the position (train position) of the train **10**, and transmits the measured train position to the ground system **30** as train position information together with identification information (e.g., train ID) about the train **10**. Note that the train position may be indicated by the distance (km) from the starting point along the track R, or may be indicated by the distance from the nearest station along the track R. It is advantageous that the train position be indicated by the distance from a given position along the track R.

The onboard system **20** corrects the train position when the train **10** has passed by a correction coil **50** (position correction coil) that is provided along the track R based on wireless communication with the correction coil **50**.

The correction coil **50** may be configured using a transceiver coil in the same manner as a known track antenna, or may be configured using radio frequency identification (RFID). The onboard system **20** and the correction coil **50** communicate with each other via short-range wireless communication.

The ground system **30** manages whether or not each block section is occupied by the train **10** based on the train position information received from the onboard system **20**.

The following description is given taking a double-track railway as an example while focusing on one of the tracks for convenience of explanation. Note that the invention may also be applied to a single-track railway, a four-track railway, and the like.

Principle

(A) Onboard Position Detection

The onboard system **20** detects the train position as described below. FIG. **2** is a view illustrating a train position detection process implemented by the onboard system **20**. The onboard system **20** determines the train position by measuring the rotational speed of the wheel set, the axle, or the wheel that is detected using a tacho-generator, an axle pulse sensor, or the like. An example in which the rotational speed is detected using a tacho-generator is described below. Since the tacho-generator is provided at a fixed position, the relative distances from the front end and the rear end of the train are constant. Therefore, the front end position Ph and the rear end position Pr of the train **10** are calculated from the measured train position and the relative distances.

In one embodiment of the invention, the front end position Ph is used as the train position. Note that the rear end position Pr may also be used as the train position. Since the train has a constant train length L, the rear end position Pr is situated backward from the train position (front end position) Ph by the train length L.

A range calculated by adding a margin distance to the range specified by the positions Ph and Pr is set to be a train occupancy range in which the train **10** may be present, taking account of a measurement error due to the tacho-generator or the like. Specifically, the onboard system **20** calculates a position Pth situated forward from the train position (front end position) Ph by a forward margin distance Ldh, and calculates a position Ptr situated backward from the rear end position Pr by a backward margin distance Ldr. The range specified by the positions Pth and Ptr is set to be the train occupancy range. In one embodiment of the invention, the train occupancy range (i.e., the front end position Pth and the rear end position Ptr) is transmitted from the onboard system **20** to the ground system **30** as the train position information.

(B) Train Position Correction Using Correction Coil **50**

A train position correction process that utilizes the correction coil **50** is described below. The onboard system **20** corrects the train position Ph when the train **10** has passed by the correction coil **50**. More specifically, the onboard system **20** communicates with the correction coil **50** to acquire the installation position (absolute position) of the correction coil **50**, and corrects the train position Ph based on the absolute position of the correction coil **50**. The onboard system **20** also corrects the rear end position Pr and the train occupancy range based on the corrected train position Ph.

FIG. **3** is a view illustrating the train position correction process that utilizes the correction coil **50**. In FIG. **3**, (**1**) indicates a state immediately before correction. In FIG. **3**, the train figure indicated by the solid line indicates the measured train position, and the train figure indicated by the dotted line indicates the actual train position. As illustrated in FIG. **3**, the measured train position Ph**1** precedes the actual front end position Ph**2**. The train occupancy range is the range specified by the positions Pth**1** and Ptr**1**.

(**2**) in FIG. **3** indicates a state in which the train position Ph has been corrected after the train has passed by the correction coil **50**. Specifically, the train position has been corrected (changed) so that the train position Ph**1** is shifted backward to the position Ph**2**. In this case, the train occupancy range is also corrected so that the train occupancy range is shifted backward to the range specified by the positions Pth**2** and Ptr**2** from the range specified by the positions Pth**1** and Ptr**1**.

When the difference ΔPh (=|Ph**1**−Ph**2**|) between the train position Ph**1** immediately before correction and the train position Ph**2** immediately after correction exceeds a predetermined value, it is determined than an abnormality has occurred, and a given process (e.g., emergency stop) is performed. The backward margin distance Ldr is used as the predetermined value when the correction direction is the backward direction, and the forward margin distance Ldh is used as the predetermined value when the correction direction is the forward direction. Specifically, the maximum position correction distance when using the correction coil **50** is the forward margin distance Ldh when the correction direction is the forward direction, and is the backward margin distance Ldr when the correction direction is the backward direction.

(C) Problem that May Occur Due to Position Correction

A problem that may occur due to the train position correction process that utilizes the correction coil **50** is described below. The ground system **30** detects whether or not each block section is occupied by a train based on the train occupancy range received from the onboard system **20**. Therefore, when the train position Ph has been shifted backward by the position correction process, a situation may occur in which the train that has completely entered one block section enters the identical block section again (or the train that has completely left one block section is positioned in the identical block section again) (i.e., the occupancy state changes).

FIG. **4** is a view illustrating the above problem that may occur due to the train position correction process. FIG. **4** illustrates an example of an occupancy detection process performed by the ground system **30**. The occupancy detection process is performed based on the train occupancy range. In FIG. **4**, (1) indicates a state before correction. In this case, the train occupancy range received from the onboard system **20** is the range specified by the positions Pth**1** and Ptr**1**. The positions Pth**1** and Ptr**1** belong to the block section **2**T. Therefore, the block section **1**T is not occupied, and the block section **2**T is occupied in this state.

For example, the onboard system **20** then corrects the train position Ph backward after the train has passed by the correction coil **50**, and the train occupancy range received from the onboard system **20** is specified by the positions Pth**2** and Ptr**2** (see (2) in FIG. **4**) (i.e., the train occupancy range has been shifted backward). In this case, the front end position Pth**2** belongs to the block section **2**T, and the rear end position Ptr**2** belongs to the block section **1**T. Therefore, the block section **1**T and the block section **2**T are occupied in this state. Specifically, the ground system **30** may detect that the block section **1**T that has been detected to be unoccupied by the train **10** that travels forward is occupied by the train **10** again.

Although FIG. **4** illustrates an example in which the rear end position Ptr of the train occupancy range is shifted backward across the boundary between the block sections, the same situation may also be applied to the front end position Pth.

(D) Detection of Unoccupancy

In one embodiment of the invention, an exit detection point Q is set at a position outside the block section, and it is determined that the train has left the block section when the entirety of the train occupancy range has passed the exit detection point Q. It is determined that the block section is not occupied when it has been determined that the train has left the block section.

FIG. **5** is a view illustrating the exit detection point that is set corresponding to the block section. In FIG. **5**, the train travels in the rightward direction. As illustrated in FIG. **5**, the exit detection point Q is set in order to determine whether or not the train has left the block section T. More specifically, a backward exit detection point Qr is set within the block section **0**T that is adjacent to the block section **1**T in the backward direction at a position away from the boundary between the block sections **0**T and **1**T by the backward margin distance Ldr. A forward exit detection point Qh is set within the block section **2**T that is adjacent to the block section **1**T in the forward direction at a position away from the boundary between the block sections **1**T and **2**T by the backward margin distance Ldr.

It is determined that the train has left the block section **1**T when it has been detected that the train occupancy range of the train is situated outside the range specified by the exit detection points Qr and Qh. Specifically, when the train travels forward, it is determined that the train has left the block section **1**T when it has been detected that the rear end position Ptr of the train occupancy range of the train has passed the exit detection point Qh. When the train travels backward, it is determined that the train has left the block section **1**T when it has been detected that the front end position Pth of the train occupancy range of the train has passed the exit detection point Qr.

FIG. **6** is a view illustrating the occupancy detection process when the train enters the block section **1**T. In FIG. **6**, the train travels in the rightward direction. The exit detection point Qr that corresponds to the block section **1**T is set within the block section **0**T that is adjacent to the block section **1**T in the backward direction.

As indicated by (1) in FIG. **6**, the train occupancy range is situated within the block section **0**T. Therefore, it is determined that the block section **0**T is occupied, and the block section **1**T is not occupied. As indicated by (2) in FIG. **6**, when the train occupancy range has been shifted forward, and the front end position Pth has passed the boundary between the block sections **0**T and **1**T, it is determined that the block section **1**T is occupied.

As indicated by (3) in FIG. **6**, the train occupancy range is then shifted backward, and the front end position Pth passes the boundary between the block sections **0**T and **1**T. In this case, since the front end position Pth has not passed the exit detection point Qr that corresponds to the block section **1**T, it is determined that the train has not left the block section **1**T, and the block section **1**T remains occupied. Since the train occupancy range is shifted backward by the margin distance Ldr to a maximum when correcting the train position utilizing the correction coil **50**, the front end position Pth may pass the boundary between the block sections **0**T and **1**T, and may be situated in the block section **0**T again. However, the front end position Pth has not passed the exit detection point Qr in the situation indicated by (3) in FIG. **6**.

As indicated by (4) in FIG. **6**, when the train occupancy range has been further shifted backward, and the front end position Pth has passed the exit detection point Qr that corresponds to the block section **1**T, it is determined that the train has left the block section **1**T, and the block section **1**T is not occupied. In this case, the train has traveled backward, and left the block section **1**T.

FIG. **7** is a view illustrating the occupancy detection process when the train leaves the block section **1**T. In FIG. **7**, the train travels in the rightward direction. The exit detection point Qh is set within the block section **2**T that is adjacent to the block section **1**T in the forward direction (travel direction).

As indicated by (1) in FIG. **7**, the front end position Pth of the train occupancy range is situated within the block section **2**T, and the rear end position Ptr is situated within the block section **1**T. Therefore, it is determined that the block section **1**T and the block section **2**T are occupied.

As indicated by (2) in FIG. **7**, the train occupancy range has been shifted forward, and the rear end position Ptr has passed the boundary between the block sections **1**T and **2**T. However, the rear end position Ptr has not passed the exit detection point Qh. Specifically, since the rear end position Ptr is situated between the boundary between the block sections **1**T and **2**T and the exit detection point Qh, it is determined that the train has not left the block section **1**T, and the block section **1**T remains occupied.

As indicated by (3) in FIG. **7**, the train occupancy range has been corrected backward due the position correction process that utilizes the correction coil **50**. Since the train occupancy range is shifted backward by the margin distance Ldr to a maximum when correcting the train position utilizing the correction coil **50**, the rear end position Ptr may pass the boundary between the block sections **1**T and **2**T, and may be situated in the block section **1**T again.

As indicated by (4) in FIG. **7**, when the train occupancy range has been shifted forward, and the rear end position Ptr has passed the exit detection point Qh that corresponds to the block section **1**T, it is determined that the train has left the block section **1**T, and the block section **1**T is not occupied. As indicated by (5) in FIG. **7**, the rear end position Ptr does not pass the boundary between the block sections **1**T and **2**T even if the train occupancy range is shifted backward due the position correction process that utilizes the correction coil **50**.

Configuration of Onboard System

FIG. **8** is a view illustrating the configuration of the onboard system **20**. As illustrated in FIG. **8**, the onboard system **20** includes an onboard processing section **100** and an onboard storage section **200**.

The onboard processing section **100** is implemented by a processor (e.g., CPU), for example. The onboard processing section **100** controls the entire onboard system **20** based on a program and data stored in the onboard storage section **200**, data received via a wireless communication device **16**, and the like. The onboard processing section **100** includes a train position measurement section **110**, a correction coil communication section **120**, a train position correction section **130**, and a train occupancy range calculation section **140**.

The train position measurement section **110** measures the position of the train based on the measured rotational speed of a tacho-generator **12** attached to the axle.

The correction coil communication section **120** acquires correction coil ID that identifies the correction coil **50** from the correction coil **50** via a receiver **14** that communicates with the correction coil **50** when the train passes by the installation point of the correction coil **50**. The correction coil **50** and the receiver **14** communicate with each other via short-range wireless communication. The maximum communication range is about 20 cm to about 1 m, and an error of the train position due to the communication range can be disregarded.

The train position correction section **130** corrects the train position measured by the train position measurement section **110** based on the communication results of the correction coil communication section **120**. More specifically, the train position correction section **130** identifies the correction coil **50** based on the correction coil ID acquired by the correction coil communication section **120** when the train passes by the installation point of the correction coil **50**, and corrects the measured train position using the corresponding absolute position. The relationship between the correction coil **50** and the installation position is provided as correction coil information **230**.

The train occupancy range calculation section **140** calculates the train occupancy range (in which the train may be present) using the train position. More specifically, the train occupancy range calculation section **140** determines the position situated backward from the train position Ph by the train length L to be the rear end position Pr. The train occupancy range calculation section **140** then calculates the position Pth situated forward from the train position Ph by the forward margin distance Ldh, and calculates the position Ptr situated backward from the rear end position Pr by the backward margin distance Ldr. The range specified by the positions Pth and Ptr is set to be the train occupancy range.

Note that the train length L is stored as train length information **210**. The forward margin distance Ldh and the backward margin distance Ldr are stored as margin distance information **220**.

In one embodiment of the invention, the forward margin distance Ldh and the backward margin distance Ldr are fixed values. Note that the forward margin distance Ldh and the backward margin distance Ldr may be set to be variable. When the forward margin distance Ldh and the backward margin distance Ldr are set to be variable, the forward margin distance Ldh and the backward margin distance Ldr are calculated based on the travel distance after the train has passed by the installation point of the correction coil **50**. Specifically, it is considered that a measurement error of the train position measured by the train position measurement section **110** increases as the travel distance from the installation point of the correction coil **50** increases. Therefore, the forward margin distance Ldh and the backward margin distance Ldr are calculated so that the forward margin distance Ldh and the backward margin distance Ldr are proportional to the travel distance. Note that the forward margin distance Ldh and the backward margin distance Ldr may be calculated so that the forward margin distance Ldh and the backward margin distance Ldr increase as the elapsed time after the train has passed by the installation point of the correction coil **50** increases.

The onboard storage section **200** is implemented by a storage device (e.g., ROM, RAM, or hard disk). The onboard storage section **200** stores a system program that causes the onboard processing section **100** to integrally control the onboard system **20**, a program and data for implementing various functions, and the like. The onboard storage section **200** is used as a work area for the onboard processing section **100**, and temporarily stores the results of calculations performed by the onboard processing section **100**, data received via the wireless communication device **16**, and the like. In one embodiment of the invention, the onboard storage section **200** stores the train length information **210**, the correction coil information **230**, and the margin distance information **220**.

Configuration of Ground System

FIG. **9** is a view illustrating the configuration of the ground system **30**. As illustrated in FIG. **6**, the ground system **30** includes an operation section **310**, a display section **320**, a communication section **330**, a ground processing section **400**, and a ground storage section **500**. Note that the configuration of the ground system **30** illustrated in FIG. **9** is merely an example, and the ground system **30** may further include an additional element.

The operation section **310** is implemented by an input device (e.g., button switch, keyboard, or touch panel), and outputs an operation signal corresponding to the operation by the user to the ground processing section **400**.

The display section **320** is implemented by a display (e.g., liquid crystal display (LCD)), and displays an image corresponding to a display signal input from the ground processing section **400**.

The communication section **330** connects to a given communication channel through the wireless base station **40**, and controls wireless communication with an external device such as the onboard system **20**.

The ground processing section **400** is implemented by a processor (e.g., CPU), for example. The ground processing section **400** controls the entire ground system **30** based on a program and data stored in the ground storage section **500**, data received via the wireless communication device **16**, and the like. The ground processing section **400** includes a train occupancy range acquisition section **410**, an occupancy state provisional detection section **420**, an occupancy change detection section **430**, a detection point passage determination section **440**, an occupancy state determination section **450**, a detection point setting section **460**, and a travel direction detection section **470**.

The train occupancy range acquisition section **410** acquires the train occupancy range (in which the train may be present) from the onboard system **20** of each train **10**. The train occupancy range acquired by the train occupancy range acquisition section **410** is stored as acquired train position information **540**.

The occupancy state provisional detection section **420** provisionally detects the occupancy state of each block section based on the train occupancy range acquired by the train occupancy range acquisition section **410**. More specifically, the occupancy state provisional detection section **420** provisionally detects that the detection target block section is occupied when the train occupancy range is situated within the detection target block section. The occupancy state provisional detection section **420** provisionally detects that the detection target block section is not occupied when the train occupancy range is not situated within the detection target block section. Note that it is determined that the train occupancy range is situated within the detection target block section even when only part of the train occupancy range overlaps the block section.

The block section setting information is provided as block section setting information **520**. FIG. **10** is a view illustrating an example of the data configuration of the block section setting information **520**. As illustrated in FIG. **10**, the block section setting information **520** includes a block section **521**, a start point position **522**, and an end point position **523**. The block section setting information **520** is basically fixed.

The detection result of the occupancy state provisional detection section **420** is stored as provisional occupancy information **550**. FIG. **11** is a view illustrating an example of the data configuration of the provisional occupancy information **550**. As illustrated in FIG. **11**, the provisional occupancy information **550** includes a block section **551**, and a provisional occupancy state **552** that has been provisionally detected.

The occupancy change detection section **430** detects a change in occupancy state of each block section. More specifically, the occupancy change detection section **430** detects whether or not the occupancy state of the detection target block section has changed from the occupancy state (determined occupancy information **560**) detected by the occupancy state determination section **450** to the occupancy state (provisional occupancy information **550**) detected by the occupancy state provisional detection section **420**. The occupancy change detection section **430** detects the state "still occupied", "still unoccupied", "occupied→unoccupied", or "unoccupied→occupied".

The detection point passage determination section **440** determines whether or not the train has passed the exit detection points Qh and Qr that are set by the detection point setting section **460** corresponding to each block section. More specifically, the detection point passage determination section **440** determines whether or not the entirety of the train occupancy range of the train has passed the exit detection point Qh by comparing the exit detection point Qh that corresponds to the detection target block section with the rear end position Ptr of the train (forward-travel train) that has been detected to travel forward by a forward-travel detection section **471**. The detection point passage determination section **440** determines that the train has passed the exit detection point Qh when the rear end position Ptr that has been situated on the backward side of the exit detection point Qh is situated on the forward side of the exit detection point Qh.

The detection point passage determination section **440** determines whether or not the entirety of the train occupancy range of the train has passed the exit detection point Qr by comparing the exit detection point Qr that corresponds to the detection target block section with the front end position Pr of the train (backward-travel train) that has been detected to travel backward by a backward-travel detection section **472**. The detection point passage determination section **440** determines that the train has passed the exit detection point Qr when the front end position Pth that has been situated on the forward side of the exit detection point Qr is situated on the backward side of the exit detection point Qr.

The occupancy state determination section **450** includes an exit determination section **451**, and detects the occupancy state of each block section using the provisional detection result of the occupancy state provisional detection section **420** and the determination result of the exit determination section **451**.

The exit determination section **451** determines whether or not the train has left each block section. More specifically, the exit determination section **451** determines that the train has left the detection target block section when the detection point passage determination section **440** has determined that the forward-travel train has passed the exit detection point Qh that corresponds to the detection target block section. The exit determination section **451** determines that the train has left the detection target block section when the detection point passage determination section **440** has determined that the backward-travel train has passed the exit detection point Qr that corresponds to the detection target block section.

The occupancy state determination section **450** determines that the detection target block section is occupied when the provisional detection result indicates that the block section is occupied. When the provisional detection result indicates that the block section is not occupied, the occupancy state determination section **450** detects the occupancy state of the detection target block section using the determination result of the exit determination section **451**. Specifically, when the provisional detection result indicates the state "occupied→unoccupied", and the determination result of the exit determination section **451** indicates that the train has left the detection target block section, the occupancy state determination section **450** determines that the detection target block section is not occupied. When the provisional detection result indicates the state "still unoccupied", the occupancy state determination section **450** also determines that the detection target block section is not occupied.

The detection result of the occupancy state determination section **450** is stored as the determined occupancy information **560**. FIG. **12** is a view illustrating an example of the data configuration of the determined occupancy information **560**. As illustrated in FIG. **12**, the determined occupancy information **560** includes a block section **561**, and a determined occupancy state **562** that has been determined (detected).

The detection point setting section **460** sets the exit detection points Qh and Qr corresponding to each block section. More specifically, the detection point setting section **460** sets the exit detection point Qr on the backward side of the detection target block section at a position away from the boundary between the detection target block section and the block section adjacent to the detection target block section by the backward margin distance Ldr. The detection point setting section **460** sets the exit detection point Qh on the forward side of the detection target block section at a position away from the boundary between the detection target block section and the block section adjacent to the detection target block section by the backward margin distance Ldr.

The margin distance Ldr may be a fixed value, or may be set to be variable. When the margin distance Ldr is set to be variable, the margin distance Ldr is determined based on the travel distance or the elapsed time after the train **10** has passed by the installation point of the correction coil **50**. Since the position of the correction coil **50** and the position of the boundary between adjacent block sections are fixed, the positions of the exit detection points Qh and Qr are also fixed. Specifically, the positions of the exit detection points Qh and Qr are determined by determining the distances from the boundary between adjacent block sections to the exit detection points Qh and Qr based on the distance from the installation point of the correction coil **50** to the boundary between adjacent block sections. For example, the distance from the boundary between the detection target block section **1**T and the block section **0**T that is adjacent to the block section **1**T in the backward direction to the exit detection point Qr is determined corresponding to the distance from the installation point of the correction coil **50** (that is situated at the nearest position in the backward direction) to the boundary between the block section **1**T and the block section **0**T (see FIG. **5**). The distance from the boundary between the detection target block section **1**T and the block section **2**T that is adjacent to the block section **1**T in the forward direction to the exit detection point Qh is determined corresponding to the distance from the installation point of the correction coil **50** (that is situated at the nearest position in the backward direction) to the boundary between the block section **1**T and the block section **2**T.

FIG. **13** is a view illustrating an example of the data configuration of the detection point setting information **530**. As illustrated in FIG. **13**, the detection point setting information **530** includes a block section **531**, a backward exit detection point Qr **532** (that is used to determine whether or not the train that travels backward has left the block section), and a forward exit detection point Qh **533** (that is used to determine whether or not the train that travels forward has left the block section).

The travel direction detection section **470** includes the forward-travel detection section **471** and the backward-travel detection section **472**, and determines the travel direction of the train based on a change in the train occupancy range acquired by the train occupancy range acquisition section **410**. The forward-travel detection section **471** detects whether or not the train travels forward based on a change in the train occupancy range. The backward-travel detection section **472** detects whether or not the train travels backward based on a change in the train occupancy range.

The ground storage section **500** is implemented by a storage device (e.g., ROM, RAM, or hard disk). The ground storage section **500** stores a system program that causes the ground processing section **400** to integrally control the ground system **30**, a program and data for implementing various functions, and the like. The ground storage section **500** is used as a work area for the ground processing section **400**, and temporarily stores the results of calculations performed by the ground processing section **400**, data received via the wireless communication device **16**, and the like. In one embodiment of the invention, the ground storage section **500** stores an occupancy detection program **510**, the block section setting information **520**, the detection point setting information **530**, the acquired train position information **540**, the provisional occupancy information **550**, and the determined occupancy information **560**.

Process Flow

FIG. **14** is a flowchart illustrating an occupancy detection process performed by the ground system **30**. The occupancy detection process is implemented by causing the ground processing section **400** to execute the occupancy detection program **510**.

When a message has been received from the onboard system **20** of the train (step **A1**: YES), the train occupancy range acquisition section **410** acquires the train occupancy range (front end position Pth and rear end position Ptr) included in the received message (step **A3**). When a message has not been received from the onboard system **20** of the train (step **A1**:

NO), the train occupancy range acquisition section **410** acquires the previous train occupancy range (step A**5**).

The travel direction detection section **470** determines the travel direction of the train based on the front end position Pth and the rear end position Ptr acquired by the train occupancy range acquisition section **410** (step A**7**). The occupancy state provisional detection section **420** provisionally detects the occupancy state based on the train occupancy range acquired by the train occupancy range acquisition section **410** (step A**9**).

A loop A process is then performed on each block section. In the loop A process, the occupancy state determination section **450** determines the occupancy state of the detection target block section. More specifically, when the provisional detection result indicates that the detection target block section is occupied (step A**11**: YES), the occupancy state determination section **450** determines that the detection target block section is occupied (step A**17**).

When the provisional detection result indicates that the detection target block section is not occupied (step A**11**: NO), the occupancy state determination section **450** determines the previous occupancy state of the detection target block section. When the previous occupancy state is an occupied state (step A**13**: NO), and the exit determination section **451** has determined that the train has not left the detection target block section (step A**15**: NO), the occupancy state determination section **450** determines that the detection target block section is occupied (step A**17**). When the previous occupancy state is an occupied state (step A**13**: NO), and the exit determination section **451** has determined that the train has left the detection target block section (step A**15**: YES), the occupancy state determination section **450** determines that the detection target block section is not occupied (step A**19**).

When the previous occupancy state is an unoccupied state (step A**13**: YES), the occupancy state determination section **450** determines that the detection target block section is not occupied (step A**19**). The loop A process is performed as described above.

When the loop A process has been performed on each block section, the process is repeated from the step A**1**.

Advantageous Effects

The wireless train control system **1** according to one embodiment of the invention is configured so that the onboard system **20** transmits the train occupancy range based on the measured train position to the ground system **30**. The ground system **30** provisionally detects the occupancy state of each block section based on the train occupancy range acquired from the onboard system **20**. The exit detection points Qh and Qr are set corresponding to each block section at a position outside each block section. It is determined that the train has left the block section when the entirety of the train occupancy range has passed the exit detection point Qh or Qr. When the provisional detection result indicates that the detection target block section is not occupied, and it has been determined that the train has left the detection target block section, it is determined that the detection target block section is not occupied. This prevents a situation in which the block section that has been detected to be unoccupied by the train that travels forward is occupied by the train again due to backward position correction using the correction coil **50**.

Modifications

The invention is not limited to the above embodiments. Various modifications and variations may be appropriately made without departing from the scope of the invention.

(A) Calculation of Train Occupancy Range

The onboard system **20** may transmit the train position instead of the train occupancy range. In this case, the ground system **30** receives the train position from the onboard system **20**. The train occupancy range acquisition section **410** calculates the train occupancy range based on the received train position.

Although only some embodiments of the present invention have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within scope of this invention.

What is claimed is:

1. An occupancy detection device that detects an occupancy state of each block section by a train, each block section being obtained by dividing a track, a correction coil being installed along the track, and the train including a measurement section that measures a train position, a correction coil communication section that communicates with the correction coil when the train passes by an installation point of the correction coil, and a correction section that corrects the train position based on a communication result of the correction coil communication section, the occupancy detection device comprising:

an acquisition section that acquires a train occupancy range that is determined based on the train position, the train occupancy range being a range in which the train may be present and being defined by a length of the train, a forward margin distance and a backward margin distance;

a provisional detection section that provisionally detects the occupancy state of each block section based on the train occupancy range;

a detection point passage determination section that determines whether or not the entirety of the train occupancy range has passed a detection point that is provided within a second block section adjacent to a first block section at a position away from a boundary between the first block section and the second block section by a given distance; and

a determination section that determines the occupancy state of the first block section using a detection result of the provisional detection section and a determination result of the detection point passage determination section.

2. The occupancy detection device as defined in claim **1**, further comprising:

an occupancy change detection section that detects whether or not the provisional detection section has detected that the occupancy state of the first block section has changed from an occupied state to an unoccupied state,

the determination section including an exit determination section that 1) determines that the train has not left the first block section when the detection point passage determination section has determined that the entirety of the train occupancy range has not passed the detection point, and 2) determines that the train has left the first block section when the detection point passage determination section has determined that the entirety of the train occupancy range has passed the detection point, after the occupancy change detection section has detected that the provisional detection section has detected that the occupancy state of the first block section has changed from the occupied state to the unoccupied state, and

the determination section determining that the first block section is occupied until the exit determination section determines that the train has left the first block section after the occupancy change detection section has detected that the provisional detection section has detected that the occupancy state of the first block section has changed from the occupied state to the unoccupied state.

3. The occupancy detection device as defined in claim **2**,

the second block section being a block section that is adjacent to the first block section in a forward travel direction of the train,

the occupancy detection device further comprising a forward-travel detection section that detects whether or not the train travels forward based on a change in the train occupancy range,

the detection point passage determination section determining whether or not the entirety of the train occupancy range has passed the detection point based on the occupancy state of the second block section detected by the provisional detection section, and a positional relationship between a rear end position of the train occupancy range and the detection point, and

the exit determination section determining whether or not the train that travels forward has left the first block section.

4. The occupancy detection device as defined in claim **2**,

the second block section being a block section that is adjacent to the first block section in a backward travel direction of the train,

the occupancy detection device further comprising a backward-travel detection section that detects whether or not the train travels backward based on a change in the train occupancy range,

the detection point passage determination section determining whether or not the entirety of the train occupancy range has passed the detection point based on the occupancy state of the second block section detected by the provisional detection section, and a positional relationship between a front end position of the train occupancy range and the detection point, and

the exit determination section determining whether or not the train that travels backward has left the first block section.

5. The occupancy detection device as defined in claim **1**, further comprising:

a detection point setting section that determines a position of the detection point by determining a distance from the boundary to the detection point based on a distance from the installation point of the correction coil to the boundary.

6. An occupancy detection method that detects an occupancy state of each block section by a train, each block section being obtained by dividing a track, a correction coil being installed along the track, and the train including a measurement section that measures a train position, a correction coil communication section that communicates with the correction coil when the train passes by an installation point of the correction coil, and a correction section that corrects the train position based on a communication result of the correction coil communication section, the occupancy detection method comprising:

provisionally detecting the occupancy state of each block section based on a train occupancy range that is determined based on the train position, the train occupancy range being a range in which the train may be present and being defined by a length of the train, a forward margin distance and a backward margin distance;

determining whether or not the entirety of the train occupancy range has passed a detection point that is provided within a second block section adjacent to a first block section at a position away from a boundary between the first block section and the second block section by a given distance; and

determining the occupancy state of the first block section using a result of the provisionally detection and a determination result as to whether or not the entirety of the train occupancy range has passed a detection point.

7. An occupancy detection system that detects an occupancy state of each block section by a train, comprising:

a track having a plurality of block sections, each track having at least one detection point located at a given distance from a boundary with an adjacent track section;

a correction coil being installed along the track;

the train including a measurement section that measures a train position, a correction coil communication section that communicates with the correction coil when the train passes by an installation point of the correction coil, and a correction section that corrects the train position based on a communication result of the correction coil communication section; and

an occupancy detection device including:

an acquisition section that acquires a train occupancy range that is determined based on the train position, the train occupancy range being a range in which the train may be present and being defined by a length of the train, a forward margin distance and a backward margin distance;

a provisional detection section that provisionally detects the occupancy state of each block section based on the train occupancy range;

a detection point passage determination section that determines whether or not the entirety of the train occupancy range has passed the detection point of a subsequent block section; and

a determination section that determines the occupancy state of a previous block section using a detection result of the provisional detection section and a determination result of the detection point passage determination section.

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